Space Technology Research Grants

Dynamics and Controls of Swarms of Femtosatellites

Completed Technology Project (2011 - 2015)

Project Introduction

The proposed research activity is focused on the development of fuel and computationally efficient guidance and control algorithms for spacecraft swarms. The guidance and control methods developed in this research will address swarms with the following characteristics: swarms will have hundreds to thousands of agents, each agent will have limited control, sensing, and communication capabilities, and the swarms will be under the influence of highly coupled, nonlinear dynamics. The proposed research will also deliver an implementation of the guidance and control algorithms using both a testbed of tens to hundreds of autonomous helicopters and a realistic simulator that captures the exact orbital dynamics. One challenge unique to the spacecraft swarm is to meet the optimal and robust performance requirement of the desired swarm behaviors governed by the highly nonlinear orbital dynamics as well as the attitude dynamics. The relatively limited control, sensing, communication, and computation capabilities of the spacecraft will further complicate the complexity of the guidance and control problems. In the field of robotics and multivehicle control, graphs have been used to solve flocking and consensus control problems with similar objectives to those of spacecraft swarms. However, this work cannot be directly applied to the guidance and control problem of spacecraft swarms. One key difference is the complexity of the dynamic models of spacecraft swarm dynamics. The algorithms developed for simple planar motions of mobile robots or aerial vehicles cannot automatically ensure either fuel-efficient or collision-free maneuvers for the swarm dynamics in the presence of various orbital perturbations. In other words, when we derive the guidance and control algorithms and conduct verification and validation (V&V), we should consider the highly nonlinear coupled time-varying dynamics with various environmental, sensor, actuator, and communication uncertainties. The field of formation flying has been very popular for the past decade and many guidance and control algorithms have been developed. Unfortunately, the size of a swarm is several orders of magnitude larger than most spacecraft formations. For this reason, the fully centralized approaches typically used in formation flying are computationally expensive because they require that the location and path of each spacecraft be known at all times. Therefore, a decentralized approach is much more computationally feasible. In this case, each spacecraft only needs to know the locations and paths of its neighboring spacecraft. Spacecraft swarms have many potential uses in interferometry and communications but they cannot perform any functions until more efficient guidance and control algorithms. Swarms will greatly outperform monolithic spacecraft in many areas due to their versatility and durability. For this reason it is critical that fuel efficient and computationally practical guidance and control approaches be developed and tested. Additionally, these algorithms can be modified for use in other fields such as robotics and multivehicle control.

Anticipated Benefits

Project Image Dynamics and Controls of Swarms of Femtosatellites

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Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Responsible Program:

Space Technology Research Grants

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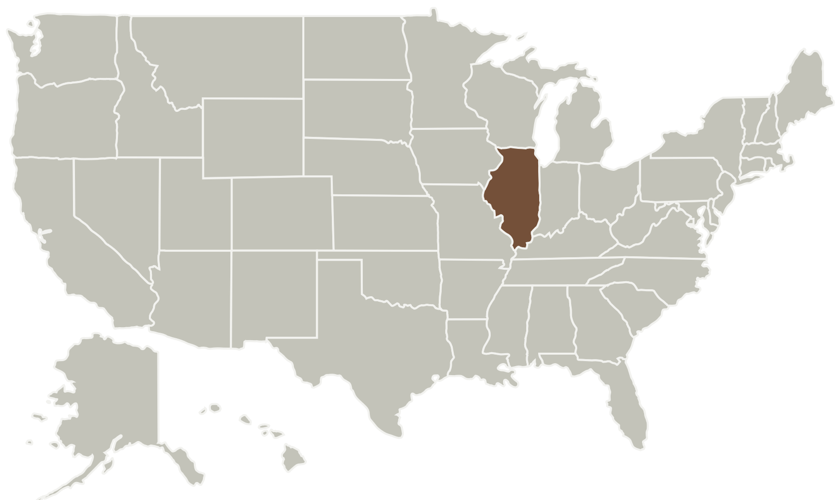
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
University of Illinois at Urbana-Champaign	Supporting Organization	Academia	Urbana, Illinois

Primary U.S. Work Locations
Illinois

Project Management

Program Director:
Claudia M Meyer

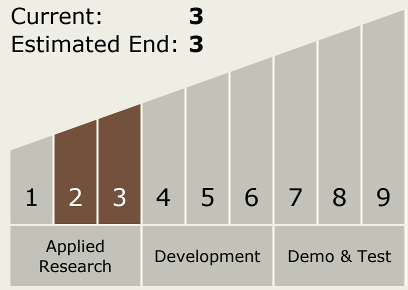
Program Manager:
Hung D Nguyen

Principal Investigator:
Soon-jo Chung

Co-Investigator:
Daniel C Morgan

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



Technology Areas

Primary:

- TX07 Exploration Destination Systems
  └ TX07.1 In-Situ Resource Utilization
    └ TX07.1.1 Destination Reconnaissance and Resource Assessment

Images

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Project Image Dynamics and Controls of Swarms of Femtosatellites
(https://techport.nasa.gov/image/1761)

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html